The Spring has been warm and wet. Cherry trees and forsythia are in full bloom, wasps and bumblebees are collecting nectar under the watchful eyes of a couple of large birds nesting under the eaves of our roof. From my window, beyond a stretch of manicured lawn, I see one of the many small lakes that dot the Michigan countryside. It is surrounded by wild raspberry bushes and by a marshy area and it is teeming with life. A few days ago, a couple of swans stopped on their seasonal migration to build their nest and raise their young, fiercely defending their territory against Canadian geese and wild ducks. As recently as yesterday, two cygnets were swimming between them. To-day one of them is gone, probably the victim of a large snapping turtle lurking in the deep. In the marshes bull frogs croak their mating song, but fall silent and take their cover to escape a stalking blue heron or a water snake which, in turn, slithers into a hole to hide from a soaring bird of prey. Fish jump out of the water to catch an insect or to escape bigger fish. Rabbits nibble on our tulip buds, while a black cat feasts on their young, but is not smart enough to leave a skunk alone. The frost, of course, is out of the ground. Robins find their worms, blue jays, cardinals and finches empty our bird feeders faster than we can fill them; the nest of sparrows under the eaves of our roof is empty; the babies have learned to fly, but continue to be fed by their elders, beak-to-beak. A crop of crab apples that had wintered on the tree, fell to the ground, thawed and fermented in the heat of the sun, much to the delight of a flock of birds which feast on them and stagger, seemingly drunk. As I open the front door, black flies and birds take to the air, woodchucks, chipmunks and other rodents run for their holes.

Am I, in the words of Charles Darwin, (Fig. 1-5) “ beholding the face of nature bright with gladness” or am I witnessing a battle for survival of the individual where the priorities are speed and guile, rather than mating and reproduction? If so, what about the “survival of the species”? Not to worry, it is in the hands of Mother Nature armed with an arsenal of weapons designed to help all living organisms find mates, recruit allies and deter enemies, that is, adapt to ever changing and often hostile environment. It is an arsenal of physical and chemical signals transmitted from individual to individual, from species to species and, as we shall see, from animals to plants and from plants to animals via the nervous system by means of five senses (hearing, smell, taste, touch and vision), through learning and experience and, at least in primates and in humans, through imponderable expressions of love, hate, disbelief, surprise and other forms of body language.

If replication and ability to cause disease in cattle, (mad cow disease) and in humans (Creutzfeld-Jacob syndrome) are accepted evidence, natural and artificially created prions, may be considered the simplest form of living organisms, otherwise the most ubiquitous, adaptable and competitive form of life are the bacteria.

Bacteria have their phages and their antibiotics. The first of these, penicillin, was discovered by Alexander Fleming in 1928. It was a “chance” discovery (in the words of Louis Pasteur: “chance favors a prepared mind”) by a man whose mind was open like the minds of the three Princes of Serendip traveling in Sri Lanka, who by “chance and sagacity were always discovering things they were not in quest of” (Horace Walpole, 1754, Fig. 6-8). Bacteria, of course, cause disease, death and the decay of dead animals and plants, making their components available for recycling. Some bacteria take over when other bacteria have been weakened by therapy and are appropriately called “opportunistic” (e.g., pseudomonas aeruginosa vs. candida albicans). Other bacteria become symbiots of fungi, molds or corals, still others secrete substances which inhibit the growth of mold or fix nitrogen and increase soil fertility or become adapted to the ice of Antarctica and the hot springs of Yellowstone, are appropriately called “extremophiles” and enter the food chain. Bacteria, of course, are unicellular organisms, nevertheless they possess signaling mechanisms which allow them to communicate, sense population density and coordinate their activity, such as secreting substances capable of overcoming the immune system and transforming themselves from opportunistic to infectious: a phenomenon called “quorum sensing”. Finally, recent evidence suggests that Plasmodium falciparum, the parasite responsible for the spread
of malaria, has become resistant to anti-malarial drugs, through mutation. Environmental factors also appear to be involved in adaptation. Thus, the European variety of St John’s wart, when grown in the United States are less resistant to infection than the native variety. Imported Eurasian grasses and a climbing vine have prospered in Oregon and in the Florida Everglades, respectively at the expense of local varieties, whole non-native plants have invaded the Galapagos Islands, much to the dismay of Darwin’s followers. These are but a few examples of the changes brought about by the actions of man. Others are the effects of logging, pesticides, industrial pollutants, field burning to obtain arable land, of the planting of genetically engineered crops and of the escape of large, aggressive and voracious carp and salmon from breeding ponds and reservoirs. The examples of man’s interference with the designs of Mother Nature are endless. Fish introduced in the Roman marshes to eat the larvae of the malaria-carrying mosquitoes ate the tadpoles of indigenous frogs. Rabbits introduced to Australia by the early settlers as a source of food took over the grasslands at the expense of native marsupials and had to be exterminated. European sparrows hitching a ride on the caravels of early explorers found abundant food and few predators and multiplied and so did the chameleon transported from its native Africa to Hawaii. Infectious *staphylococci* and *streptococci* must be killed by antibiotics, letting the white cells and the immune system finish the job, lest a few antibiotic-resistant mutants take over the field (Fig. 9-13).

Animals and plants secrete many substances which, in turn, they perceive through the 5 senses mentioned above:

1. **Vision** and the perception of color and light, the functions of the lens and of the retina. Visual acuity is used to advantage by diurnal (eagles) and nocturnal (owls) birds of prey to the detriment of species, like snakes, rabbits and other small animals upon which they feed. The anglerfish uses bioluminescence to draw smaller fish toward its large jaws and powerful teeth, while sensitivity to the spectral wavelength is used to advantage by some insects which can see color in the dark and by animals, such as the chameleon, the coral grouper and some insects which adapt to the color or the shape of the environment for purposes of camouflage or, as in the fireflies, as a mating call. Finally, vision can be used as a threat (animals may be paralyzed by fear) or, as in the case of multiple lenses of the housefly, to detect direction of an oncoming peril. Most flowering plants arrange their leaves and petals to maximize the plant’s light gathering ability (Fig. 14-18, 36). While the orange-red fluorescence of certain Caribbean corals is due to symbiotic co-existence with nitrogen-fixing cyanobacteria.

2. **Hearing**, that is “the subjective perception of sound;”, as distinguished from the vibrations that cause it, form the threatening roar of a lion, the growling of a guard dog and the shouts of a surging hoard of barbarians, to the sweet notes of an opera star or the endearing voice of a lover. Can the vibrations produced by wind and thunder or by a tree crashing in the forest or by an army of termites chewing up the foundations of your house be considered a sound if there are no ears to hear them?

3. **Tasting** or the use of flavors (bitter, sweet, sour and salty, as perceived by the tongue, as contrasted to odors by the nose) as a defense or offensive weapon. The monarch butterfly is protected from predatory birds by a bitter look alike. The aspen secretes a glucoside that repels the Gypsy moth. Newts, salamanders and toads secrete substances which irritate the skin and the mucosal membranes of potential predators. One of them, tetrodotoxin, is poisonous to snakes, but he stomach of some snakes secrete an enzyme which digests it. The Komodo Dragon kills its prey by spitting foul smelling and infected saliva at it, while the skin of some poisonous frogs and toads contains alkaloids that can kill a predator which may be attracted to the amphibian’s bright color. The venom of the cobra contains an anticoagulant which accelerates the death of the snakes prey, other poisonous snakes, vampire bats and Gila monsters repel predators by secreting poisonous substances of potential therapeutic value, such as Captopril, a peptide found in the venom of a Brazilian viper, commonly used to block the action of angiotensin and lower blood pressure or Integrilin, the synthetic analog of a substance found in the venom of the Pygmy rattlesnake, which retards platelet aggregation and blood clotting and is useful in the therapy of heart attacks or during heart surgery. Slugs can distinguish edible mushrooms from muscarine-containing poisonous toadstools. The seeds of the cycada, a plant that grows in some Pacific islands, contain a neurotoxin and birds will not touch them; nicotine, atropine and digitalis may serve to protect the tobacco plant, the blueberry look-alike Belladonna bush and the Foxglove from insects and herbivores.
Finally, the papillae of the human tongue can distinguish sugar from sugar substitutes, detect lingering after-taste of saccharine and, while some individuals can taste the bitterness of certain chemicals (phenylthiocarbamide or PROP) others do not. Perhaps this is why some people like broccoli and spinach and some do not, why caterpillars avoid certain plants, why spiders secrete venoms designed to kill predators and victims alike. Alternatively, some of these phenomena may prove that taste like smell is subject to adaptation (it could be argued that protracted exposure to bright light or loud sounds do not lead to adaptation, but to blindness and deafness). The observations that certain plants, such as the European St. John’s Wort, when grown in the United States, are less resistant to insects and suffer more infection and mortality then the native variety, suggests that taste, just as smell and vision, may be subject to adaptation (Fig. 19-24, 55-57, 59-64)

4. Smelling and the perception of odors and of pheromones, from the aromas wafting out of a baker’s oven, a broiler of a Starbucks Café, to the attar of roses and other perfumes that attract pollinators or hapless insects into the Venus Flytrap. Indeed, it has been shown that the human brain can identify and remember about ten thousand different odors, a feat dwarfed by dogs and other animals that use their nose to establish territoriality, to recognize friend or foe, to find food and receptive mates in a familiar or new environment (like the descendants of domestic pigs turned feral in Hawaii) or the victims of nature’s fury. Skunks spray potential predators with a characteristic foul-smelling repellant. Ants use pheromones to lead other ants to the best sources of food. Mosquitoes are attracted by the odor of lactic acid and other components of sweat. Odor (or perhaps heat) may be a guide to food for tarantulas and snakes. Newts and salamanders secrete tetrodotoxin which is poisonous to snakes, but an enzyme in the stomach of garter snakes digests it. Some toads repel potential predators by secreting an irritant to skin and mucosal membranes. A molecule engineered into tomatoes attracts flies that feed on parasitic caterpillars, but perhaps the most amazing observation is that, by smelling her genitals, a male mouse can tell if a female is pregnant with his pups or with those of a rival and, if they are not his, he will eat them at birth. Thus, smelling serves not only to find a partner ready for sex, but to protect the lineage of the animal’s DNA. Odors attract flies that feed on tent caterpillars and effectively repel other caterpillars that destroy tomato crops. Nor is odor a weapon only used by animals. Indeed, some plants secrete volatile terpenes which attract wasps whose eggs become larvae hungry for the caterpillars which eat the plant’s leaves. The wings of the Jewel beetle, Malanophila acuminata can absorb the thermal radiations emitted by wildfires as far as 80 kilometers away, transforming the insect into a “living fire detector”, while the smoke and heat of burning vegetation promotes germination of a variety of plants, including some of the Redwoods (Fig. 25-32).

5. Touching and the ability to feel the roughness and the temperatures of a surface and to use them as mechanisms of defense and feeding. The sting of nettles and thorns of a rose bush and of a desert cactus will dissuade a potential herbivore, the papillae of the tongue or the sensory ending of the tip of one’s fingers can separate the prick of two very close needles, the temperature of a spoonful of soup may prove too hot to swallow, the carapace of a turtle, the skin of a rhino, the armor of the armadillos and saltwater sticklebacks may prove hard to crack, the bony horn of the flat-tailed lizard and the quills of a porcupine may dissuade a potential predator. On the other hand, the sucker arms of an octopus are exquisitely structured to provide agility of movement, while the raspy surface of the donkey’s and mouse’s tongue are structured to hold even the smallest morsel of food. A combination of sight, touch and smell may allow birds to recognize their own brood, although parasitic Cowbirds have learned to lay their eggs in some one else’s nest and share parental resources and care. Plants use thorns, tough bark and sticky resins to discourage the herbivores and insects, although hungry deer have been known to feed on the bark of trees when snow is deep, and the thick tongue of the donkey allows it to feed on thistles and nettles. Nicotine, atropine, digitalis and muscarine protect tobacco, belladonna, foxglove plants and poisonous fungi from herbivores and slugs. The bark of the Aspen secretes a glucoside that repels the Gypsy moth as well as the Tent caterpillar. Finally, the swimming and the excrements of the Dascillus, a plankton-eating fish, provide aeration and food for plankton itself and for a species of coral, which in turn, provides shelter for the fish (Fig. 33-41).

6. Learning or the process by which previous experience determines the behavior of animals, whether it has been an individual or a species experience. Thus, naïve gazelles will run away from a lion, although they
had never seen a lion before, blue tits use information from past years to synchronize their nesting with peak insect abundance, while the first image seen upon hatching remains imprinted in the mind of birds, even if it is that of an artificial adult. Guile, may be looked upon as a form of atavistic memory: upon sighting a boa constrictor a mongoose will inflate itself with inhaled and swallowed air, allow the snake to wrap itself around its body, deflate, escape and bite the snake’s head off. Learning and the conscious memory of learned experiences is, of course, developed best in primates and humans. Young chimpanzees learn from their elders to crack oil-palm nuts with stones, captive capuchin monkeys learn to perform complex tasks, to evaluate the reward and adjust the complexity of the response accordingly, monkeys on the Japanese island of Koshima have learned from their elders to wash the dirt off sweet potatoes. Chimps raised in the Kyoto Primate Research Institute yawn when deprived of a usually rewarding task and their young imitate them. As in humans, the signs of boredom appear to be contagious. Indeed, brain scanning techniques have provided evidence that some intellectual activities, such as the self-righteous pride felt by a person observing someone being punished for some wrong doing, can be localized in precise areas of the human brain. Indeed, learning to communicate appears to be an innate and spontaneous phenomenon as demonstrated by the sign language invented by a group of unschooled deaf Nicaraguan children (Fig. 42-57).

SUMMARY and CONCLUSIONS.

1. Without survival of the individual there cannot be survival of the species.
2. Food and safe shelter are the primary goals of all animal and plant species.
3. Nature had provided a rich arsenal of weapons to insure these goals.
4. In addition, Nature seems to be very resourceful in adapting to unforeseen circumstances, which often result from human activities.
5. Among these activities is increased biodiversity due to the creation of new transgenic species, of natural mutation or, simply, the introduction of alien species into new environments.
6. Of these new species, the “fittest” will survive, evolve, and affect the evolution of other species, while others will become extinct by “Natural Selection”.
7. The phenomena described in this paper are fully compatible with Darwin’s predictions. In addition, they suggest that evolution may trespass the boundaries of species within the animal and the vegetable kingdom, but an inter-kingdom evolution allowing plants and animals to survive and prosper. Thus, we can predict the evolution of transgenic species created using the techniques of molecular biology such as pigs with human genes useful as a source of organs for human transplants, or goats whose milk contains a spider protein useful to make ropes stronger than any designed by man.
8. In conclusion, it may be noted that, in most animal species, the female is anatomically and physiologically suited to insure survival of the species. In the human female this role is achieved by suggestive behavior, revealing manner of dress, perfumes and other means of seduction. After fertilization, the role of the male is no longer biologic and becomes that of providing physical, psychological and social support. A role which could also be interpreted an a Darwinian sense.
9. In a future “brave new world” endangered species will be saved from extinction using their DNA preserved in the frozen state.
Fig. 49

Fig. 50

Fig. 51

Fig. 52

Fig. 53

Fig. 54

Fig. 55

Fig. 56

Fig. 57
There once was a lady who swallowed a fly.
I don't know why.
To kill the fly she swallowed a spider
that wriggled and wriggled and jiggled inside her.
To kill the spider she swallowed a toad
who dove her nuts in her gut.
To get rid of the toad she swallowed a snake
Then a cat to get rid of the snake.
But the cat tore apart her inside and, in the end,
she did die.
Because she had swallowed a fly.

Yum, yum. Snakes use special tricks to eat
other snakes. Trace the two tails to see who is
eating whom.

First class. Colorful enough for a Swiss stamp
sticklebacks have captivated a growing num-
ber of biologists.

Flat-tailed horned lizard in defensive
posture.
Blown Away by Chimps

Visitors to the new chimp habitat at the Chicago zoo may be in for a surprise: harmless blasts of air that the animals can aim at gawkers by touching a keypad.

SCIENCE VOL 305 16 JULY 2004

The LOOK of LOVE

Mother chimp has fishing probe in her mouth.

SCIENCE VOL 306 15 OCTOBER 2004
BIBLIOGRAPHIC SOURCE AND SUGGESTED READINGS


Also see the article by Robert S. Boyd entitled: “Project freezes DNA of at risk specie”: in the Detroit Free Press of October 14, 2004, p. 18A.